

parallel channels increase faster than the corresponding drop in channel bandwidth.

Consequently, the bandwidth density per channel layer, BW/p, is of primary concern. It is also desirable that the total system bandwidth increase as the density of the parallel channels increases. Figure 2 shows a plot of bandwidth density vs. data channel pitch for a 0.75m "SPEEDBOARD" backplane. It can be seen from Figure 2, however, that the bandwidth-density reaches a maximum at a channel pitch of approximately 1.2 mm. Any change in channel pitch beyond this maximum results in a decrease in bandwidth density and, consequently, a decrease in system performance. The maximum in bandwidth density occurs when the conductor and dielectric losses are approximately equal.

The backplane connector performance can be characterized in terms of the bandwidth vs. bandwidth-density plane, or "phase plane" representation. Plots of bandwidth vs. bandwidth density/layer for a 0.5m FR-4 backplane, and for 1.0m and 0.75m "SPEEDBOARD" backplanes are shown in Figure 3, where channel pitch is the independent variable. FR-4 is another well-known PCB material, which is a glass reinforced epoxy resin. It is evident that, for a given bandwidth density, there are two possible solutions for channel bandwidth, *i.e.*, a dense low bandwidth "parallel" solution, and a high bandwidth "serial" solution. The limits on bandwidth-density for even high performance PCBs should be clear to those of skill in the art.

Backplane System

Figure 4 shows a schematic of a backplane system B in accordance with the present invention. Backplane system B includes a substrate S, such as a multilayer board (MLB) or a printed circuit board (PCB). A waveguide W mounts to substrate S, either on an outer surface thereof, or as a layer in an inner portion of an MLB (not shown).

Waveguide W transports electrical signals between one or more transmitters T and one or more receivers R. Transmitters T and receivers R could be transceivers and, preferably, broad band microwave modems.

Preferably, backplane system B uses waveguides having certain characteristics. The preferred waveguides will now be described.

Air Filled Rectangular Waveguide Backplane System

Figure 5 depicts a closed, extruded, conducting pipe, rectangular waveguide 10. Waveguide 10 is generally rectangular in cross-section and is disposed along a waveguide axis 12 (shown as the z-axis in Figure 5). Waveguide 10 has an upper broadwall 14 disposed along waveguide axis 12, and a lower broadwall 16 opposite and generally parallel to upper broadwall 14. Waveguide 10 has a pair of sidewalls 18A, 18B, each of which is generally perpendicular to and connected to broadwalls 12 and 14. Waveguide 10 has a width a and a height b. Height b is typically less than width a. The fabrication of such a waveguide for backplane applications can be both difficult and expensive.

Figure 6 depicts the current flows for the TE $1,0$ mode in walls 14 and 18B of waveguide 10. It can be seen from Figure 6 that the maximum current is in the vicinity of the edges 20A, 20B of waveguide 10, and that the current in the middle of upper broadwall 14 is only longitudinal (*i.e.*, along waveguide axis 12).

According to the present invention, a longitudinal gap is introduced in the broadwalls so that the current and field patterns for the TE $1,0$ mode are unaffected thereby. As shown in Figure 7A, a waveguide 100 of the present invention includes a pair of conductive channels 102A, 102B. First channel 102A is disposed along a waveguide axis 110. Second channel 102B is disposed generally parallel to first channel 102A to define a gap 112 between first channel 102A and second channel 102B.

Gap 112 allows propagation along waveguide axis 110 of electromagnetic waves in a TE $n,0$ mode, where n is an odd integer, but suppresses the propagation of electromagnetic waves in a TE $n,0$ mode, where n is an even integer. Waveguide 100 suppresses the TE $n,0$ modes for even values of n because gap 112 is at the position of maximum transverse current for those modes. Consequently, those modes cannot propagate in wave guide 100. Consequently, waves can continue to be propagated in the TE $1,0$ mode, for example, until enough energy builds up to allow the propagation of waves in the TE $3,0$ mode. Because the TE $n,0$ modes are suppressed for even values of n, waveguide 100 is a broadband waveguide.

Waveguide 100 has a width a and height b. To ensure suppression of the

TE_{n,0} modes for even values of n , the height b of waveguide 100 is defined to be about $0.5a$ or less. The data channel pitch p is approximately equal to a . The dimensions of waveguide 100 can be set for individual applications based on the frequency or frequencies of interest. Gap 112 can have any width, as long as an interruption of current occurs.

- 5 Preferably, gap 112 extends along the entire length of waveguide 100.

As shown in Figure 7A, each channel 102A, 102B has an upper broadwall 104A, 104B, a lower broadwall 106A, 106B opposite and generally parallel to its upper broadwall 104A, 104B, and a sidewall 108A, 108B generally perpendicular to and connected to broadwalls 104, 106. Upper broadwall 104A of first channel 102A and upper
10 broadwall 104B of second channel 102B are generally coplanar. Gap 112 is defined between upper broadwall 104A of first channel 102A and upper broadwall 104B of the second channel 102B.

Similarly, lower broadwall 106A of first channel 102A and lower broadwall 106B of second channel 102B are generally coplanar, with a second gap 114 defined
15 therebetween. Sidewall 108A of first channel 102A is opposite and generally parallel to sidewall 108B of second channel 102B. Side walls 108A and 108B are disposed opposite one another to form boundaries of waveguide 100.

An array of waveguides 100 can then be used to form a backplane system 120 as shown in Figure 7B. As described above in connection with Figure 7A, each
20 waveguide 100 has a width, a . Backplane system 120 can be constructed using a plurality of generally "I" shaped conductive channels 103 or "C" shaped conductive channels 102A, 102B. Preferably, the conductive channels are made from a conductive material, such as copper, which can be fabricated by extrusion or by bending a sheet of conductive material. The conductive channels can then be laminated (by gluing, for example), between two
25 substrates 118A, 118B, which, in a preferred embodiment, are printed circuit boards (PCBs). The PCBs could have, for example, conventional circuit traces (not shown) thereon.

Unlike the conventional systems described above, the attenuation in a waveguide 110 of present invention is less than 0.2 dB/meter and is not the limiting factor
30 on bandwidth for backplane systems on the order of one meter long. Instead, the